Sensing Room and Its Resident Behavior Mining

Taketoshi Mori
The University of Tokyo.
7-3-1 Hongo.
Bunkyo, Tokyo 1138656 Japan
tmori@ics.t.u-tokyo.ac.jp

Ryo Urushibata
The University of Tokyo.
7-3-1 Hongo.
Bunkyo, Tokyo 1138656 Japan
urushib@ics.t.u-tokyo.ac.jp

Masamichi Shimosaka
The University of Tokyo.
7-3-1 Hongo.
Bunkyo, Tokyo 1138656 Japan
simosaka@ics.t.u-tokyo.ac.jp

Tomomasa Sato
The University of Tokyo.
7-3-1 Hongo.
Bunkyo, Tokyo 1138656 Japan
tomo@ics.t.u-tokyo.ac.jp

Akinori Fujii
The University of Tokyo.
7-3-1 Hongo.
Bunkyo, Tokyo 1138656 Japan
fujii@ics.t.u-tokyo.ac.jp

Hajime Kubo
The University of Tokyo.
7-3-1 Hongo.
Bunkyo, Tokyo 1138656 Japan
kubo@ics.t.u-tokyo.ac.jp

Kana Oshima
The University of Tokyo.
7-3-1 Hongo.
Bunkyo, Tokyo 1138656 Japan
oshima@ics.t.u-tokyo.ac.jp

Hiroshi Noguchi
The University of Tokyo.
7-3-1 Hongo.
Bunkyo, Tokyo 1138656 Japan
noguchi@ics.t.u-tokyo.ac.jp

CHI 2009, April 4 – April 9, 2009, Boston, MA, USA
ACM 978-1-60558-247-4/08/04.

Abstract
We have been constructing several room-type support systems for over 10 years. Both informational and robotic supports are performed based on collected massive sensor data of the rooms. For example, in the room called "Sensing Room", nearly 1,000 sensors are distributed, and behavior data are accumulated automatically and annotated by hand afterward watching the recorded video for mining-based autonomous support. Sensing Room have many types of sensors and monitors human activities without restriction of occupants. Support system includes steerable active projector on the ceiling, several displays and speakers. Based on the accumulated activities, the support system decides timing, position and contents fitting the occupants' activities. We will show our 'know-how' of constructing and using Sensing Room, and introduce some related researches like annotated motion data based recognition, behavior modeling based on long-term pyroelectric motion sensors data.

Keywords
Activity Modeling, Behavior Capture, Context aware computing, Pervasive Sensing, Intelligent House

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

Introduction

Smart room is one of important research area in everyday-aware pervasive computing [1-4]. In smart rooms, massive sensors and computers are distributed usually invisibly. The smart rooms monitor habitants' activities and the room situations with various sensors. The rooms support the habitants attentively based on measured situations and captured human activities. Typical applications are home automations such as brightness adaptation to the room environment, air conditioning fitting to the personal preference, and automatic collaboration of audio-visual appliances. In the near future, the smart rooms will support the habitants actively. For instance, the room will notify important information with displays or audio devices. Robots in the room may support home tasks (e.g. bringing some house commodities).

Sensing Room

From late 90's, we have been construction room-type human support system called Sensing Room. Sensing Room is developed as a typical studio-type room[5]. The room includes all room function except lavatory and bathroom. The size of room is about 5m x 4.5m. Sensing Room contains about 1,000 sensors, which are mainly pressure sensors. Room photo and room layout are illustrated in Fig. 1 and 2.

figure 1. Sensing Room (Current Late 2008).

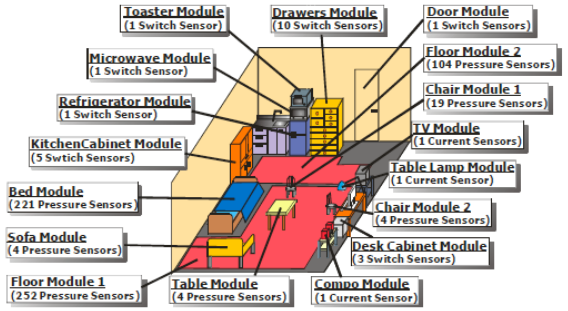

figure 2. Modules Used in Sensing Room

Sensing Room has several groups of sensor and they are categorized into modules. The sensors attached on the same objects or the same kinds of sensors are clustered into a module. The grouping policy is based on how sensors are introduced into the rooms. One way is introduction with new appliances and furniture. i.e. when the new appliance comes into the home or when old ones are replaced with new ones, the sensors are embedded in new appliance. Managing sensors attached on the same object as one unit is adaptable to modification of room layout. The other way is embedding sensors into the room beforehand or attaching sensors on the room after building. In this case, single sensor is often meaningless, but bulk of distributed sensors is beneficial. These sensors are often managed with single control box. Examples of the sensor are surveillance cameras, door switches and pyroelectric sensors. Both two type of grouping are regarded as clustering sensors that connect to the same control box into one unit. Currently in Late 2008, Sensing Room sensors are grouped into 18 modules. The Sensors in the module are managed by small micro controller-based computers, and the data are collected

using a sophisticated home-oriented network middleware [6].

Behavior Pattern Classification in Sensing Room

In Sensing Room, we tried a human life summarization for understanding and describing daily life in a short time. The architecture consists of two processes. One is a human life clustering process, in which time-series data of human life are divided into some behavior-based clusters. The other is a display process, in which the time-series segments are displayed instantly recognizable along with the time. The experimental results showed that the configuration is able to divide human life record into apprehensible segments on time series(Fig.3). The work also showed that a prototype of the summarization system and proved that people can comprehend overview of the life with it [7]. The research is enhanced to deal with long-term pyroelectric motion sensors set in solitary elder person living in the country-side house [8,9].

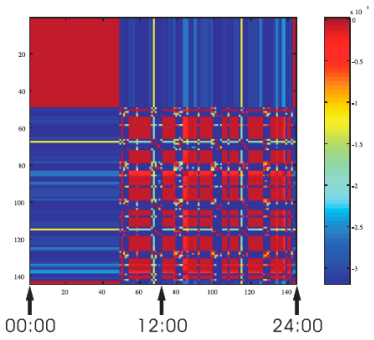

figure 3. A Clustered Behavior Feature Array

Behavior Prediction in Sensing Room

We proposed a behavior prediction system using Sensing Room. The prediction system is for supporting our daily lives. The behaviors in daily-life are recorded in Sensing Room with embedded sensors, and the prediction system learns the characteristic patterns that would be followed by the behaviors to be predicted. In the system, a method of discoverying time-series association rules, which discovers frequent combinations of events called episodes. The prediction system observes behaviors with the sensors and outputs the prediction of the future behaviors based on the rules [10].

Motion Database and Action Recognition in Sensing Room

We took some daily behaviors using several different type of Sensors and added text annotations manually for developing learning-based method of residents' support. Since an ordinal room contains many obstacles for cameras or optical sensors, we used magnetic motion captured system to obtain human motions. We modeled human motion as about 20DOF joint movements, and converted them into BVH format. There may be many point of view for categorizing behaviors, we added multi-labels to each motions, concretely speaking, multiple behavior names for every time frames. The annotated database are open widely by WWW [11].

Using the database, we have developed several behavior segmentation algorithms, behavior modeling algorithms and behavior recognition algorithms[12-14]. We also extended these researches for multi-camera based system [15].

.

Conclusion

Through our Sensing Room research, we proposed importance of behavior capture method, annotated behavior database, data-driven learning algorithms, data management middleware and collaborative development based on these. We hope the research area grows based on shared massive data contributed by research people seeking for the same target application of new era.

Reference

[1] Intille, S.S.: Designing a home of the future. IEEE Pervasive Computing 1 (2002) 76-82.

[2] Mori, T., Asaki, K., Noguchi, H., Sato, T.: Accumulation and summarization of human daily action data in one-room-type sensing system. In: Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems(2001), 2349-2354.

[3] Kidd, C.D., Orr, R.J., Abowd, G.D., Atkeson, C.G., Essa, I.A., MacIntyre, B., Mynatt, E., Starner, T.E., Newstetter, W.: The aware home: A living laboratory for ubiquitous computing research. In: Proceedings of the Second International Workshop on Cooperative Buildings. (1999) 191-198.

[4] Brumitt, B., Meyers, B., Krumm, J., Kern, A., Shafer, S.: Easyliving: Technologies for intelligent environments. In: Handheld and Ubiquitous Computing. (2000) 12-27.

[5] Mori, T., Noguchi, H., Takada, A., Sato, T.: Sensing room: Distributed sensor environment for measurement of human daily behavior. In: First International Workshop on Networked Sensing Systems (INSS). (2004) 40-43.

[6] Noguchi, H., Mori, T., Sato, T.: Network middleware for flexible integration of sensor processing in home environment. In: Proceedings of IEEE International Conference on Systems, Man and Cybernetics (2004) 3845-3851.

[7] Mori, T., Takada, A., Iwamura, Y.: Automatic Human Summarization System in Sensory Living Space. In: Proceedings of IEEE System, Man and Cybernetics (2004) 1583-1588.

[8] Mori, T., Fujii, A., Shimosaka, M., Noguchi, H., Sato, T.:Typical Behavior Patterns Extraction and Anomaly Detection Algorithm Based on Accumulated Home Sensor Data. In: International Workshop on Smart Home (SH'07) (2007) 51-57.

[9] Mori, T., Urushibata, R., Shimosaka, M., Noguchi, H., Sato, T.: Anomaly Detection Algorithm Based on Life Pattern Extraction from Accumulated Pyroelectric Sensor Data. In: Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (2008) 1151-1158.

[10] Mori, T., Takada, A. Noguchi, H., Harada, T., Sato, T.: Behavior Prediction Based on Daily-Life Record Database in Distributed Sensing Space. In: Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (2005) 1833-1839.

[11] ICS Action Database. http://www.ics.t.u-tokyo.ac.jp/action/.

[12] Shimosaka, M., Nishimura, T., Nejigane, Y., Mori, T., Sato, T.: Fast Online Action Recognition with Boosted Combinational Motion Features. In: Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (2006) 5851-5858.

[13] Shimosaka, M., Mori, T., Sato, T.: Efficient Margin-Based Query Learning on Action Classification. In: Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (2006) 2778-2784.

[14] Segawa, Y., Shimosaka, M., Mori, T., Sato, T.: Human Like Segmentation of Daily Actions based on Switching Model of Linear Dynamical Systems and Human Body Hierarchy. In: Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (2006) 5859-5865.

[15] Sagawa, Y., Shimosaka, M., Mori, T., Sato, T.: Fast Online Human `Pose Estimation via 3D Voxel Data. In: Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (2007) 1034-1040.